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13. ABSTRACT (Maximum 200 words) A wide variety of problems in digital signal processing were studied, with emphasis on the scalability of architectures for large array processors, timing and reliability limits in large arrays, delay performance of statistical multiplexers, robust signal processing, and digital image coding and processing. Results in the study of array processors include the development of a particular architecture that scales very well for iterative computations on a regular lattice, and a testing method particularly suited to lattice-gas computations. Related work describes design methods for redundant arrays, and arrays that incorporate error detection and correction. In the study of the delay performance of statistical multiplexers, a method is given for computation of the queue-length probability distribution function in the presence of voice traffic. The work in robust signal processing studies the effect of incomplete information on the performance of matched filters. An approach is presented for the compression of color images with limited palette size that does not require color quantization of the decoded image. For comparable quality and bit rates, the proposed technique significantly reduces the decoder computational complexity. Finally, different approaches are compared for block motion compensation coding of interlaced sequences. It is shown that proper use of that redundancy can significantly improve the coding efficiency.					
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DIGITAL SIGNAL PROCESSING

FINAL REPORT

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Authors: Ken Steiglitz, Bede Liu, Professors

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1. Statement of Problems Studied

A wide variety of problems in digital signal processing were studied, with special emphasis on

- Scalability of architectures for large array processors
- Timing and reliability limits in large array processors
- Delay performance of statistical multiplexers
- Robust signal processing
- Digital image coding and processing.

2. Summary of Most Important Results

All of the research results obtained during execution of this grant were reported in journal articles and conference papers. We give here brief summaries of the major contributions; reference numbers are to the list of publications in the last section.

Scalability of architectures for large array processors [6, 12, 21, 34]

This work is the focus of Squier's Ph.D. dissertation and culminates in [34]. The main result is showing that a particular architecture scales very well for iterative computations on a regular lattice. Other related work reports a testing method particularly suited to lattice-gas computations [12, 21], and performance tests of a prototype machine built by Kugelmass from custom chips [6].

Timing and reliability limits in large arrays processors [2, 16, 18, 19, 23, 24, 27, 28, 29, 30]

References [18, 19, 24, 27, 28, 30] report work on the design of redundant networks, and describe methods for incorporating error detection and correction in large array processors. References [2, 16] explore the practical limits on throughput imposed by timing in a long, self-timed pipeline. It is shown that linear speedup can be achieved with utilization approaching 100%. The main conclusion in [23, 29] is that as a one-dimensional array gets very long, tree clocking becomes preferable to straight-line clocking.

Delay performance of statistical multiplexers [4, 9, 11, 17]

The introduction of packet switching techniques for voice transmission motivates the analysis of the performance of statistical multiplexers, measured in terms of delay. The main result in these papers is a method for computation of the queue-length probability distribution function in the presence of voice traffic.

Robust signal processing [8, 26, 32]

A matched filter's performance is strongly related to the signal being detected, and can be shown to be optimal when that signal is an eigenvector of the noise correlation matrix corresponding to a minimum eigenvalue. When fewer correlations are known than would be necessary to specify such an eigenvector, it is natural to choose a signal which is robust to the implied uncertainty in the noise dependency structure. This is

shown to be tantamount to finding a tight upper bound on the minimum eigenvalue over all correlation matrices within the uncertainty class. Such a bound is achieved by the reduced correlation matrix of order equal to the number of available correlations, and hence the robust signal is shown to have this length. No matter how reasonable, any assumption used to extend the correlation matrix can degrade performance; a system designer should not try to use information he or she does not have.

Digital image coding and processing [25, 31]

Color images are usually compressed in a luminance-chrominance coordinate space. Since the compression is done independently for each coordinate, the pixels of the decoded image can take any value in the full color space. If such a compression technique is applied to an image using a limited palette, the decoded image has to be quantized before it can be displayed with a limited palette. In [25], we present an approach for the compression of color images with limited palette size that does not require color quantization of the decoded image. For comparable quality and bit rates, the proposed technique significantly reduces the decoder computational complexity.

Motion compensation techniques developed for progressively scanned sequences are not efficient when applied to interlaced sequences because of the particular structure of these sequences. In [31] we compare different approaches for block motion compensation coding of interlaced sequences. Simulation results show that techniques using independently the even and odd fields do not perform consistently for various camera motions. We introduce a new technique that facilitates the use of the redundancy that exists between consecutive and similar fields. It is shown that proper use of that redundancy can significantly improve the coding efficiency.

3. Participating Scientific Personnel

A. Faculty Supported in Part by this Grant:

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C. Ph. D. Dissertations Completed:

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1. O. Au, "Signal Detection in Non-Gaussian Transformations," October 1990.
2. F. Brochin, "Delay Performance Analyses for Statistical Multiplexers," December 1989.
3. R. Squier, "Efficient, Scalable Architectures for Lattice-Gas Computations," June 1991.
4. A. Zaccarin, "Coding of Digital Pictures: fast and efficient techniques," July 1991.

4. Publications

1. M. L. Honig, K. Steiglitz, B. Gopinath, and S. Boyd, "Bounds on Maximum Throughput for Digital Communication with Finite-Precision and Amplitude Constraints," submitted for publication.
2. M. R. Greenstreet and K. Steiglitz, "Bubbles can make Self-Timed Pipelines Fast," *Proc. 1989 Conf. on Information Sciences and Systems*, Johns Hopkins University, March 22-24, 1989, pp. 624-630.
3. P. M. Crespo, M. L. Honig, and K. Steiglitz, "Optimization of Pre- and Post-Filters in the Presence of Near- and Far-End Crosstalk," *Proc. IEEE Int. Conf. on Communications*, Boston, MA, June 1989.
4. F. Brochin and J. B. Thomas, "Statistical Multiplexer Performances for Voice Traffic with Hyperexponentially Distributed Voice Silence Periods," *Proc. 1989 Conf. on Information Sciences and Systems*, Johns Hopkins University, Baltimore, MD, March 22-24, 1989; pp. 700-705.
5. F. Brochin and J. B. Thomas, "Voice/Data Transmission in Packet Form: A Study of Delay Performances," *Proc. 1989 IEEE Pacific Rim Conf. on Communications, Computers, and Signal Processing*, Victoria, BC, June 1-2, 1989; pp. 218-221.
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17. F.M. Brochin and J.B. Thomas, "A Three-State Markov Chain Model for Speech Dynamics and Related Statistical Multiplexer Delay Performance," *Journal of the Franklin Institute*, Vol. 327, No. 6, 1990, pp. 903-921.
18. E. H.-M. Sha and K. Steiglitz, "Explicit Constructions for Reliable Reconfigurable Array Architectures," Third IEEE Symposium on Parallel and Distributed Processing, accepted.
19. E. H.-M. Sha and L.-F. Chao, "Design for Easily Applying Test Vectors to Improve Delay Fault Coverage," IEEE Int. Conference on Computer-Aided Design, Santa Clara, CA, Nov. 1991, accepted.
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26. D.G. Warren and J.B. Thomas, "Asymptotically Robust Detectors and Estimators for Very Heavy-Tailed Noise," *IEEE Transactions on Information Theory*, vol. 37, no. 3, May 1991, pp. 475-481.
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